EFFECTS OF TYPES OF FAT AND OF RATES AND TEMPERATURES OF COMMINUTION ON DISPERSION OF LIPIDS IN FRANKFURTERS

SUMMARY—The effect of time, temperature and rpm of comminution of emulsions was determined on the dispersion of approximately 25% of beef fat, pork fat or cottonseed oil in frankfurters. The numbers of lipid particles 5 μ or less in diameter increased in frankfurters containing either beef or pork fat as comminution was continued to higher temperatures, with pork fat dispersed more thoroughly. Fat tended to separate from frankfurters containing beef fat in particles 200 μ or more in diameter. In contrast, no specific degree of dispersion of particles 5 μ or less in diameter consistently indicated emulsion stability, or its lack. Increased rpm during comminution produced an increased dispersion of beef or pork fat. Under the same conditions pork fat was dispersed more finely than beef fat. Dispersion of cottonseed oil produced finely dispersed particles beyond the resolution of light microscopy, as was confirmed by electron microscopy which showed a substantial number of particles to be less than 1 μ in diameter.

INTRODUCTION

THIS ARTICLE is the second reporting results of a study of the effects of varying types of fat and of rates and temperatures of comminution on the processing and properties of frankfurters. Data on the viscosity of emulsions and on the processing, specific gravity, skin strength and elasticity of the frankfurters have been reported (Townsend et al., 1971). The results of a histological study of the dispersion of lipids in those frankfurters containing approximately 25% fat are reported here. Histological studies concerned with the formation of membranes which enclose fat have been relatively thorough (Hansen, 1960; Swift et al., 1961; Helmer and Saffle, 1963; Borchert et al., 1967); however, only limited data exist on the size and dispersion of fat particles (Saffle, 1968). The results reported deal with the effects of the processing parameters on dispersions and any relation of variations of these dispersions to emulsion stability.

EXPERIMENTAL

Samples

The samples were obtained from lots of frankfurters containing approximately 25% beef fat, pork fat or cottonseed oil: preparation involved comminuting emulsions at 1,500, 2,500 or 5,000 rpm to temperatures ranging from 45 to 85°F, stuffing, and cooking and smoking (Townsend et al., 1971). After preparation, those reserved for histological examination were stored under vacuum in polyester pouches at 0°F.

Histological preparation

The samples were allowed to thaw and were placed in buffered 10% neutral formalin for 2 wk. Sections removed from the center of these were cooled to −4°F and 16-μ sections were cut. These were mounted on chilled slides wetted with chrome glycerine jelly. They were then sprayed with a freshly prepared dilute solution of egg albumen, after which the slides were inverted over formalin for 1 min. The sections were stained 5 min in 0.5% solution of Sudan Black-B in 70% ethanol, washed in water, counterstained 5 min in 0.1% aqueous solution of nuclear fast red (Kernechtrot), washed in water and mounted in chrome glycerine jelly.

Estimation of size and number of fat particles

Measurements were made with a Bausch & Lomb Dynazoom microscope. A linearly scaled eyepiece micrometer disc was used in measuring size and a squared grid in counting numbers. The discs were calibrated for use at magnifications of 100 and 400×. Particles having diameters of 200 μ, or larger, were counted in 0.5-mm² areas of five sections prepared from 1–2 frankfurters at a 100× magnification. Particles having diameters of 5 μ, or less, were counted in three 625-μ² areas of sections prepared from a frankfurter in each treatment lot at a 400× magnification: the results are reported as particles per 0.5 mm².

Photomicrography

Photomicrographs were taken with a Zeiss microscope equipped with a 25/0.63 planoapochromat lens using Kodak High Contrast copy film.

Electron microscopy

Small pieces (¼-sq in.) were cut from the center of the frankfurters. The samples were prepared by prefixing in 5% glutaraldehyde in 0.1M phosphate buffer at pH 7.45 for 2 hr (Borchert et al., 1967). The samples were removed from the glutaraldehyde and cut into small blocks (~1 mm²) and washed overnight in 0.2M sucrose buffered with 0.1M phosphate at pH 7.45. The small blocks were fixed in 1% OsO_4 in 0.1M phosphate buffer for 4 hr. Embedding in epoxy resin was performed (Luft, 1961). Gold to silver sections were cut on an L.K.B. Ultratome III, stained with uranyl acetate and lead citrate and examined with an RCA EMU-3G electron microscope at 50 k.V. accelerating voltage.

RESULTS & DISCUSSION

TABLE 1 shows the average numbers of particles 5 μ or less in diameter in 0.5-mm² sections of frankfurters in which beef or pork fat was the principal lipid. A comparison of the data on frankfurters from which fat separated during heat processing (underlined) with those of the remaining frankfurters shows that no given dispersion consistently indicated emulsion stability or its lack. In general, the numbers of small particles increased as comminution was continued to higher temperatures. Results of statistical analyses applied to the linear regressions (Chow, 1960) indicate that increased dispersion was obtained with increased rpm during comminution; i.e., comminution of beef fat produced dispersion in the decreasing order 5,000 (C), 2,500 (B) and 1,500 rpm (A), and comminution of pork fat in the decreasing order 5,000 (F) and 2,500 (E). Results also indicate that pork fat was more finely dispersed than beef fat comminuted at each of the rates; i.e., at 5,000 rpm, F > C; at 2,500 rpm, E > B and at 1,500 rpm, D > A. On applying the histological technique and microscopic examinations to frankfurters containing cottonseed oil, the lipid particles counted were approximately one-half the numbers reported in Table 1. As will be further discussed, photomicrographs of these samples showed a larger number of small closely packed particles than were formed with the other lipids.

Table 2 shows the results of determinations of lipid particles having diameters 200 μ, or larger. The data indicate that in frankfurters from which fat separated during processing (underlined) larger numbers of particles of this size were observed. The results also indicate that numbers of large particles were considerably smaller in frankfurters in which pork fat was the principal lipid. Frankfurters containing cottonseed oil as the principal lipid were free of large particles; fat had not separated from them or those prepared with pork fat during heat processing. As would be expected, the decrease of large particles shown in Table 2 coincides with the increase of small particles shown in Table 1. As compared with counting small particles, the ease and significance of measuring the size of large particles recommends the measurement for use in process and product development.

Photomicrographs a to e inclusive (Fig.

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Fig. 1—Photomicrographs (400×) of emulsions containing 25% beef fat comminuted at 2,500 rpm to (a) 45°F, (b) 55°F, (c) 65°F, (d) 75°F and (e) 82°F, (f) at 1,500 rpm to 71°F, (g) at 5,000 rpm to 85°F, (h) emulsion containing pork fat comminuted at 5,000 rpm to 85°F, (i) emulsion containing cottonseed oil comminuted at 5,000 rpm to 85°F, (j) electron micrograph of emulsion containing cottonseed oil comminuted at 5,000 rpm to 85° (10,400×). (Continued next page.)

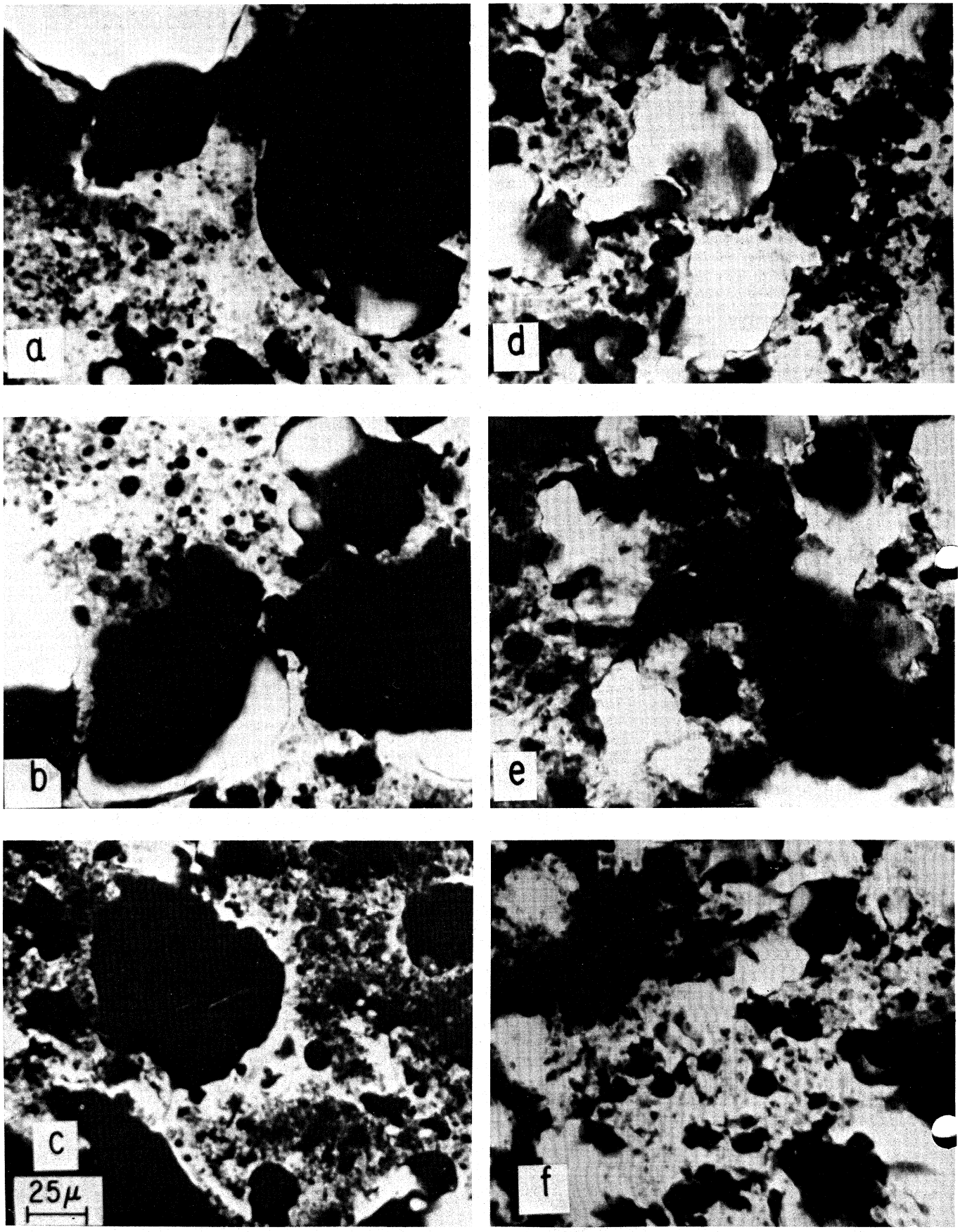

Fig. 1—Concluded

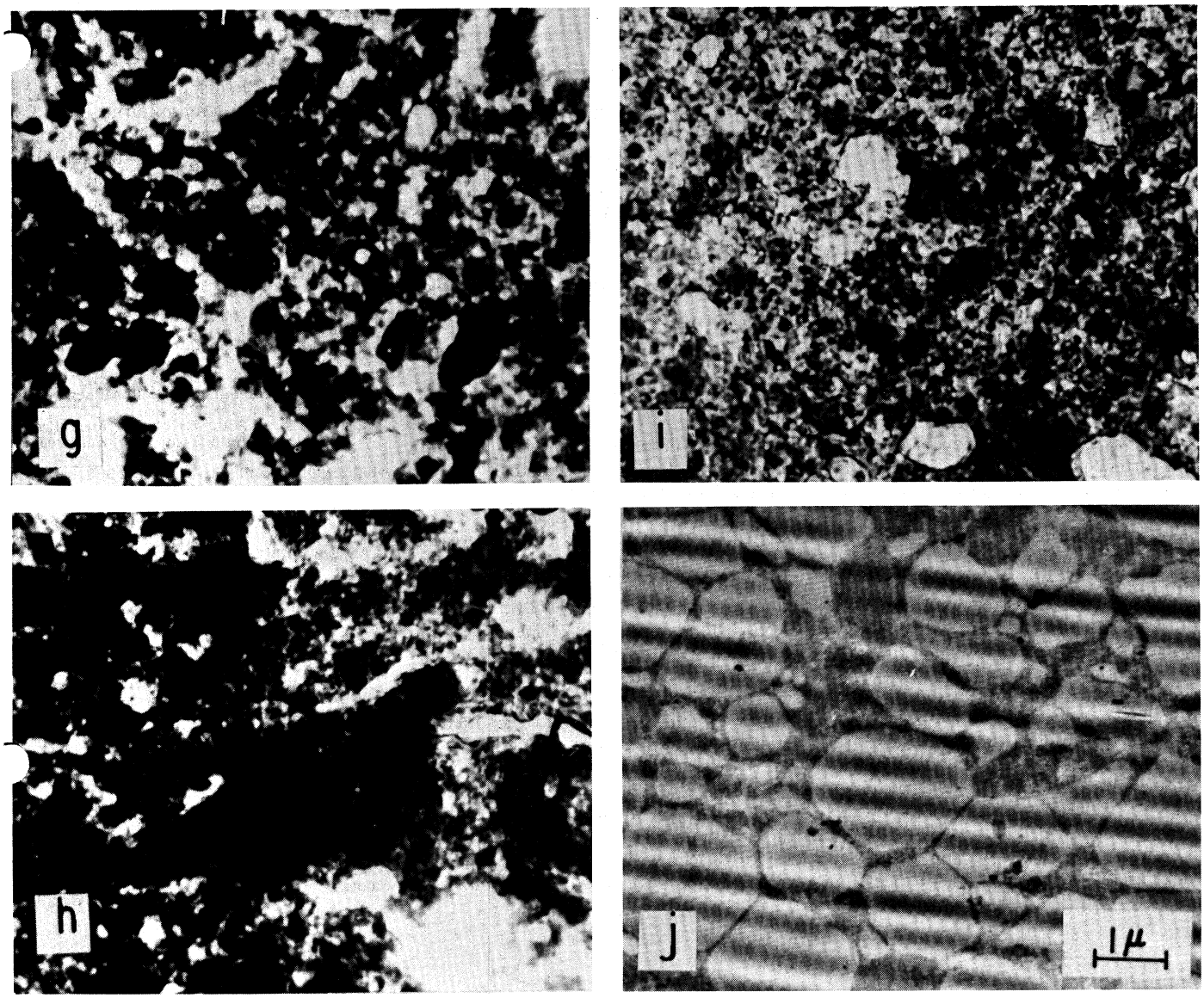

Table 1—Average numbers of small lipid particles in 0.5 mm² sections of frankfurters.

Series	Type fat	Emulsification (rpm)	Particles 5μ diameter or less per 0.5 mm² / 10² [a] Emulsification temperature (°F) 45	55	65	69	71	75	79	82	85
A	Beef	1,500	2550 ± 175 [b]	3340 ± 465	3960 ± 560	---	4090 ± 165	---	---	---	---
B		2,500	3135 ± 375	4140 ± 350	4090 ± 255	---	---	4720 ± 330	---	5470 ± 270	---
C		5,000	3690 ± 355	4475 ± 280	5025 ± 195	---	---	5690 ± 90	---	---	5500 ± 410
D	Pork	1,500	3570 ± 260	4080 ± 320	5235 ± 725	4760 ± 725	---	---	---	---	---
E		2,500	---	3950 ± 330	4230 ± 195	---	---	5440 ± 465	5965 ± 315	---	---
F		5,000	---	5160 ± 505	5490 ± 530	---	---	6340 ± 630	---	---	7230 ± 990

[a] Results of tests of equality between sets of coefficients of pairs of linear regressions (Chow, 1960).

B > A, P < 0.025
C > B, P < 0.01
C > A, P < 0.01

D = E, n.s.

F > E, P < 0.01
F > D, P < 0.10
D > A, P < 0.01
E > B, P < 0.05
F > C, P < 0.01

[b] Underlines indicate fat separation occurred in cooking these lots (Townsend et al., 1971).

Table 2—Particles 200 μ or more in diameter in sections of frankfurters prepared with beef fat or pork fat.[a]

	Emulsification										
			Temperature (°F)								
	Rpm	Fat	45	55	65	69	71	75	79	82	85
A	1,500	Beef	4.2[b]	4.0	2.45	—	0.65	—	—	—	—
		Pork		0.8	0.8	0.4	—	—	—	—	—
B	2,500	Beef	3.6	4.6	3.4	—	—	0.45	—	2.0	—
		Pork	—	2.4	1.2	—	—	0.5	0.8	—	—
C	5,000	Beef	3.2	4.8	3.4	—	—	1.65	—	—	0.65
		Pork		1.8	0.8	—	—	0.2	—	—	0

[a]Average of five replications on 0.5-mm^2 sections.
[b]Underlines indicate fat separation occurred in cooking these lots (Townsend et al., 1971).

1) show as black areas the dispersion in frankfurters prepared with 25% beef fat from emulsions comminuted to temperatures ranging from 45–82°F at 2,500 rpm. Comminuting at 45 (a), 55 (b) or 65°F (c) failed to produce adequate dispersion as shown by the separation of fat from the frankfurters in the smokehouse (Townsend et al., 1971). Comminuting to 75°F (d) produced the relatively fine dispersion shown in frankfurters from which fat did not separate. The poorer dispersion obtained on extended chopping to 82°F (e) illustrates the effects of overchopping which produces coalesced fat during lengthy chopping to relatively high temperatures (Townsend et al., 1971).

Photomicrographs f, d and g show as black areas the dispersion of beef fat frankfurters prepared from beef fat emulsions chopped at 1,500 rpm to 71°F (35 min), 2,500 rpm to 75°F (15.3 min) or 5,000 rpm to 85°F (6.8 min), respectively. The finest of the three dispersions is that shown in photomicrograph g. The results, as well as those shown in Table 1, indicate that chopping at 5,000 rpm not only produced a finer dispersion at a given temperature, but that achieving the equivalent was not possible by an extension of chopping at 1,500 or 2,500 rpm, since 71 and 75°F were the highest attainable temperatures yielding stable emulsions.

Photomicrographs g, h and i show as black areas the dispersion obtained in frankfurters containing beef fat, pork fat or cottonseed oil, respectively, as the principal lipid prepared from emulsions comminuted at 5,000 rpm to 85°F. They show the dispersion of lipids to be in the increasing order beef fat, pork fat and cottonseed oil. Photomicrograph j prepared using an electron microscope shows as light areas the dispersion of cottonseed oil obtained on comminuting at 5,000 rpm to 85°F. The appreciable portion of small particles, some approximately 0.1 μ as described by Borchert et al. (1967), accounts for the problem encountered in counting particles in studying dispersions of this fat using light microscopy.

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